ESD-TDR-64-585

Quarterly Progress Report

Division 4

Radar

15 December 1964

Prepared under Electronic Systems Division Contract AF 19(628)-500 by

Lincoln Laboratory
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Lexington, Massachusetts

The work reported in this document was performed at Lincoln Laboratory, a center for research operated by Massachusetts Institute of Technology, with the support of the U.S. Air Force under Contract AF 19(628)-500.

Quarterly Progress Report

Division 4

Radar

15 December 1964

Issued 12 January 1965

Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Lexington, Massachusetts

INTRODUCTION

This report summarizes the General Research activities of Division 4 during the period 1 September through 30 November 1964. The General Research activities in Division 4 involve Groups 42 and 46 on Haystack Instrumentation, Group 44 on Phased Arrays, and Group 45 on Millimeter Waves. The activities of the Division for Project PRESS, on Radar Discrimination, the BMRS Program, Space Communications, and Project Apollo are described in separate reports.

J. Freedman
Head, Division 4

H. G. Weiss
Associate Head

15 December 1964

Accepted for the Air Force
Stanley J. Wisniewski
Lt Colonel, USAF
Chief, Lincoln Laboratory Office

TABLE OF CONTENTS

REPORTS BY AUTHORS IN DIVISION 4

15 September through 15 December 1964

PUBLISHED REPORTS

Technical Report

TR No.				DDC and Hayden Nos.
365	The Haystack Experimental Facility	H. G. Weiss	15 September 1964	DDC 608272

Group Report

No.				
1964-59	Dynamic-Range Reduction of Video Signals by Amplitude Compression	R. D. Behn	16 November 1964	DDC* H-

Journal Articles†

JA No.			
2249	The Application of Semiconductor Optical Radiators to Space Communication	B. S. Goldstein J. D. Welch	Trans. IEEE, Commun. Electron. 83, 470 (1964)
2338	Multidimensional Parameter Estimation by the Summed Weighted Least Squares Minimization of Remainders	H. Schneider	J. Astron. Sci. 11, 61 (1964)
2338A	Addendum to "Multidimensional Parameter Estimation by the Summed Weighted Least Squares Minimization of Remainders"	H. Schneider A. R. Warwas	J. Astron. Sci. 11, 77 (1964)
2341	Vacuum Voltage Breakdown as a Thermal Instability of the Emitting Protrusion	G. E. Vibrans	J. Appl. Phys. 35, 2855 (1964)
2407	Array Antennas: New Applications for an Old Technique	J. L. Allen	IEEE Spectrum 1, No. 11, 115 (1964)

* Not yet assigned.

† Reprints available.

UNPUBLISHED REPORTS

Journal Articles

JA No.			
2428	Circulator Synthesis	J. A. Weiss	Accepted by Trans. IEEE, PTGMTT
2433	Bounds on the Volume and Height Distributions of the Ambiguity Function	R. Price* E. M. Hofstetter	Accepted by Trans. IEEE, PTGIT
2453	A Solid State Room-Temperature-Operated GaAs Laser Transmitter	G. F. Dalrymple B. S. Goldstein T. M. Quist	Accepted by Proc. IEEE
2470	The Evaluation of Diode Parameters Using a Transmission Measuring Technique	C. Blake F. J. Dominick	Accepted by Micro Waves

Meeting Speeches†

MS No.			
540C	Slow Motion Sound (film)	D. A. Cahlander	Seminar, M.I.T., 15 October 1964
1065	A Description of a High Performance Microwave Ground Terminal	H. G. Weiss	8th AGARD Avionics Symposium, London, 21-25 September 1964
1077	The Application of Higher Order Waveguide Modes to High-Power, Dual-Polarized Tracking Horns	K. J. Keeping	IEEE, PTGAP Symposium, New York, 22-24 September 1964
1152	Progress and Problems in High-Power Phasers for Array Radar	D. H. Temme	NEREM, Boston, 4-6 November 1964
1158	Modulation of GaAs Injection Lasers	B. S. Goldstein R. M. Weigand J. D. Welch	NEREM, Boston, 4-6 November 1964
1157	Some Observations on Vaccum Voltage Breakdown at About 50 kv	G. E. Vibrans	International Symposium on Insulation of High Voltages in Vacuum, M.I.T., 19-21 October 1964
1163	The Superposition of Selected Waveguide Modes to Achieve Desirable Features in the Aperture Distribution of Dual-Polarized Tracking Radars	K. J. Keeping	URSI-IEEE Meeting, University of Illinois, 13-15 October 1964
1241	The Engineer and Research	C. W. Jones	Student IEEE Meeting, University of Maine, 18 November 1964

* Division 6.

† Titles of Meeting Speeches are listed for information only. No copies are available for distribution.

ORGANIZATION

DIVISION OFFICE

Jerome Freedman, *Division Head*
Herbert G. Weiss, *Associate Head*
George F. Watson, *Assistant*

GROUP 41

D. L. Clark, *Leader*

M. Axelbank
S. L. Borison
E. M. Hofstetter
H. M. Jones
J. J. G. McCue
J. B. Resnick
H. O. Schneider
C. B. Slade
D. M. Towle
R. E. VanderSchuur

GROUP 42

A. A. Galvin, *Leader*
W. W. Camp, *Associate Leader*

M. E. Austin
D. R. Bromaghim
D. A. Cahlander
D. R. Carey
G. F. Dalrymple
W. H. Drury
J. C. Fielding
B. S. Goldstein
H. J. Greenberger
H. M. Heggestad
J. Horwitz
A. A. Kalis
B. Loesch
J. Margolin
G. R. McCully
S. Spoerri
C. M. Steinmetz
J. H. Teele
R. M. Weigand
J. D. Welch

GROUP 43

R. C. Butman, *Leader*
G. L. Guernsey, *Associate Leader*

L. B. Anderson
R. S. Bailey
A. J. Bogush
M. P. Fraser
P. A. Ingwersen, Jr.
W. A. Janvrin, Jr.
J. G. Jelatis
P. B. McCorison
G. B. Morse
M. E. Schwarz, Jr.
E. Silverman
A. Vierstra

GROUP 44

J. L. Allen, *Leader*

D. M. Bernella
F. Betts
L. Cartledge
W. P. Delaney
B. L. Diamond
S. D. Ewing
W. J. Ince
T. B. Lewis
H. J. Pratt, Jr.
M. Siegel
E. Stern
D. H. Temme

GROUP 45

W. W. Ward, *Leader*
J. P. Perry, *Associate Leader*
S. J. Miller, *Assistant Leader*

G. R. Armstrong
A. Bertolini
W. A. Both
S. F. Catalano
J. R. Cogdell
D. F. DeLong
M. W. Dill
B. H. Labitt
D. F. Mayer
C. J. McKenney
W. B. Renhult
R. G. Sandholm
R. W. Straw
R. P. Wishner

GROUP 46

C. W. Jones, *Leader*
C. Blake, *Assistant Leader*

W. A. Andrews
L. W. Bowles
A. A. L. Browne
F. J. Dominick
W. D. Fitzgerald
W. J. Getsinger
K. J. Keeping
A. H. Kessler
E. P. McCurley
C. E. Muehe, Jr.
F. I. Sheftman
A. F. Standing

RADAR SIGNAL PROCESSING
GROUP 42

I. INTRODUCTION

Group 42 presently supports four Laboratory projects: PRESS, Radar Discrimination Technology, Apollo and Haystack.

The PRESS and Radar Discrimination Technology activities are described in Semiannual Technical Reports to ARPA, and the activities on Apollo are recorded in bimonthly progress reports to NASA. A description of the work on Haystack Instrumentation is given here.

II. HAYSTACK INSTRUMENTATION

A. Sequential Doppler Processor

The sequential Doppler processor was delivered to the site during the first week of October.

B. Monopulse Angle Estimator

Laboratory testing of the monopulse angle estimator has been completed. This system will be shipped to the Haystack site in December.

C. Test Signal Generator and Target Simulator

Most of the equipment for the test signal generator and target simulator has been shipped to the site and installed. Site testing will take place during the next reporting period. The IF section (100- and 130-Mcps chassis) is at the Laboratory undergoing final tuneup.

D. X-Band Distance Measuring System

Work has been continuing on the ground-based electronics associated with the X-band antenna contour measuring equipment. The results of preliminary tests have been favorable.

ARRAY RADARS
GROUP 44

I. 900-Mcps TEST ARRAY

The 900-Mcps test array was operated throughout this reporting period without any important problems. It was demonstrated to interested persons within the Laboratory and again as part of a phased-array briefing held for the Navy Bureau of Weapons. It was decided that the 900-Mcps test array development was complete and little more would be gained by continuing to operate the array. The operation was terminated, and the resources it used will be devoted to new developments.

II. S-BAND TEST FACILITIES

The subarray antenna test pattern range was operated during this reporting period. Some inaccuracies caused by poor bearing alignment were eliminated and patterns of single elements and of some four-element configurations were taken.

III. POWER SOURCES (S-Band)

The high-power test oscillator which had been ordered was delivered and is in operation.

Work on the power supply modulator for the 100-kw S-band traveling-wave tube is nearing completion.

IV. HIGH-POWER PHASERS

For the S-band subarray phasers, it was necessary to improve the method of introducing the switching wires in the helical ferrite phaser. Reactive RF bypasses are required and must be properly spaced.

A computer program for the analysis of a waveguide with a ferrite slab has been written and checked out. The program includes calculation of dielectric and magnetic loss and the magnetic field in the ferrite so that optimum ferrite configurations for various power levels can be determined. Some experimental confirmation has been obtained. During the next reporting period, it is planned to record the results and describe the experimental checks in a report.

V. TIME DELAYS

Increased emphasis is being placed on the development of suitable ferrite switches for high-power time delays. Initial studies will utilize a ferrite switch made with two 90° helical ferrite phasers and two hybrids. Parallel work on a circulator configuration described by J. Weiss* has been restarted. New and significant approaches are being sought from industry.

* J. A. Weiss, "Circulator Synthesis," 1964 PGMTT Digest, p. 60-63.

VI. IMPROVED DYNAMIC RANGE S-BAND TUNNEL DIODE AMPLIFIER

Phase I of a two-part subcontract, let to the Radio Corporation of America for the development of a tunnel diode amplifier with improved dynamic range, has been completed. The main Phase I objective was to demonstrate achievement of a saturated output power of about −10 dbm (1-db compression) with a noise figure less than 6 db. A prototype amplifier and a final report have been delivered. The characteristics of the amplifier are as follows:

Center frequency	2.86 Gcps
Gain	17.3 db
1.5-db bandwidth	120 Mcps
Noise figure	5.6 db
Power output (1-db compression)	−13.7 dbm
Stability	Unconditional
Spurious output of intermodulation products (at 1-db gain compression point)	−41 dbm maximum
Dynamic range per megacycles per second receiver bandwidth	83.6 db

The salient features of the design are:

(1) Use of low-inductance diode package (≈50 ph),

(2) Gain obtained in two cascaded stages,

(3) Use of high-peak current diodes,

(4) Use of gallium arsenide diode by the output stage.

Phase II of the subcontract will test the reproducibility of the amplifier design by construction of three additional amplifiers. Further work on improving the existing design is also under consideration.

VII. MULTIPLE-BEAM FORMING

The final report on the series-fed multiple beam-forming matrix has been written and included in a forthcoming technical report. This final report discusses the theoretical analysis and the computed results of antenna performance as a function of network efficiency, bandwidth, nonoptimum component values, and number of elements for linear array beam formers. As a result of the series-fed, multiple beam-forming investigation, an effort is being made to evaluate the use of a nonreciprocal four-port coupler in the series-fed configuration to reduce multiple path effects in the beam former. An X-band coupler using ferrite techniques has been constructed for testing purposes.

An investigation has been started into the feasibility of replacing the hyperbolic reflector in a Cassegrainian antenna system with a phase-shifted planar reflect-array and/or an apparent movement of the phase center of the primary feed by switching, as a method of providing limited electronic scan in large parabolic reflector antennas. Past work on related techniques (such as mechanical subreflector motion) has indicated that scans of several beamwidths may be possible (with negligible pattern degradation) for reflectors with sufficiently large focal length to diameter ratios. A two-dimensional ray-tracing computer program has been written and initial results are expected within a few weeks.

VIII. MUTUAL COUPLING

Computer calculations of gain and impedance variations for linearly polarized, planar arrays of short and half wave dipoles have been completed. The final report of this portion of the program has been written and is being incorporated into a forthcoming technical report. During the next reporting period, small arrays of hybrid-fed, crossed-dipole-pair arrays (e.g., circular polarized arrays) will be investigated, which will necessitate slight modifications to the existing computer programs.

Construction of 10 by 10 and 9 by 9 element L-band planar arrays of linear dipoles was completed and experiment driving impedance data, as a function of scan angle, have been collected for comparison with the computer data. The agreement has been quite good.

The mathematical solution for the mode excitation of a typical element of an array of rectangular waveguides with negligible wall thickness has been obtained. It is in the form of an infinite set of simultaneous equations in an infinite number of unknowns (the mode excitation coefficients). A computer program is being written to solve a truncated set of these equations. The result will yield the impedance variation of such an array with scan angle, to a degree of accuracy limited only by the truncation.

Construction of a small L-band open-waveguide array is under way to provide experimental data for comparison with the computed results.

RANGE MEASUREMENTS
GROUP 45

I. INTRODUCTION

The principal activities of Group 45 are under the Program in Radar Discrimination Technology (RDT) and are reported in the Semiannual Technical Summary Reports to ARPA of the RDT Program.

II. MILLIMETER-WAVELENGTH SYSTEMS

The millimeter-wavelength systems project affords the opportunity for: (a) experimental equipment development, (b) study of millimeter-wavelength space communications, and (c) research in radar and radio astronomy. Work under these headings has been described in detail in previous quarterly progress reports. The project now consists principally of tasks in radiometry and radio astronomy.

A. 8-mm Radar

A small revival of interest in the 8-mm lunar radar occurred during this reporting period. A reconsideration of the upgrading of both the radar transmitter and receiver is under way. Group 46 has assumed the responsibility for the paper design of a transmitter using the Watkins-Johnson 1000-watt-average-power tube.

Laboratory personnel recently witnessed tests of a 35-Gcps parametric amplifier which would lower the receiver temperature by approximately 5 db. This amplifier has been developed by the Laboratory for Electronics, Electronics Division, under an Air Force contract, and may be turned over to Lincoln Laboratory for further testing, improvement, and possible application, when the contract has been fulfilled. A new radar system utilizing these improvements in the transmitter and receiver would have a signal-to-noise improvement of approximately 14 db over the system used in the successful experiment of spring, 1963.

B. Antenna System

The question of the pointing accuracy of the antenna system, discussed in previous quarterly progress reports, is still one of great importance. Attempts to understand the vagaries of the antenna pointing have been unsuccessful. During this report period, an empirical approach was adopted. Pointing errors in a limited region of the sky (that traversed by the strong radio source in Taurus) were mapped in detail by sighting on stars passing through that region. Consistency from night to night was not very good. When corrections so obtained were applied, measured errors indicated an accuracy of 1.0 minutes of arc rms. This level of accuracy would seem marginal for the acquisition of reliable data on optically invisible radio sources. However, recent computer reduction of the data taken last spring, when pointing difficulties were not appreciated, has shown the data to be much better than had been expected. We are encouraged by these results to proceed with observations of Taurus A and shall begin such a program soon.

There has been evidence in recent months that the gain of the antenna is decreasing, presumably due to weathering of the antenna surface. Since this decrease in antenna gain is of considerable importance, the evidence bearing on it will be summarized.

Direct-Gain Measurements:– Direct-gain measurements are made by comparison with a standard-gain horn; that is, signals from the antenna are attenuated so that they are equal to those received by a horn antenna of calculatable gain. The gain of the 28-foot antenna is approximately 45 db greater than that of the horn antenna, so the accuracy of this method depends upon the calibration of an RF attenuator (in practice, two in series) over the range 0 to 45 db, a challenging measurement in itself. By measurements of this type, the antenna gain was measured at: 67.6 db/matched isotrope in April, 1963; 67.0 db in January, 1964; 66.4 db in May, 1964; and 66.2 db in October, 1964. After the second measurement, it was realized that much of the protective coating was gone, leaving the reflecting surface exposed in places. Between the second and third measurement the antenna was given two coats of paint. The last measurement was made with a slightly improved method that checks for internal consistency – which proved poor and indicated that a recalibration of the RF attenuators is needed. On the whole, however, these direct measurements indicate that the antenna gain is decreasing at a rate of approximately 0.7 db per year.

Radiometric Measurements:– Indirect estimates of antenna gain can be made from measurements of radio sources. The moon has been observed periodically over the same time span as the gain measurements just described. The temperature measured for the subterrestrial point can be compared with the best current theory of lunar temperatures. When such a comparison is made, no degradation of antenna gain is indicated. However, owing to the peculiar combinations of lunar phases observed, this conclusion could be reversed if the time-varying component of the emitted radiation were assumed smaller (as some evidence suggests). Observations of Venus have been made during the past two inferior conjunctions. Normalizing for differences in distance, the temperature measured in June, 1964, was 2.2 db lower than that measured in December, 1962. Indirect estimates of antenna-gain decrease are, therefore, somewhat equivocal.

Another type of radiometric measurement can also provide information about the condition of the antenna surface. The antenna gain can be affected by either an increase in the rms surface tolerance or a decrease in the reflecting properties of the surface. In the first case, energy would be scattered out of the main lobe of the antenna; in the second, energy would be absorbed by the antenna surface. The two should be distinguishable on the basis of antenna temperature, and measurements were made with the following result. The zenith sky temperature was measured with the feed splash plate removed and was found to be 98°K, which can be accounted for by three components: 82° due to feed-line loss (1.46 db), 5° due to reflection of mixer noise, and 11° for atmospheric emission (oxygen and water vapor). When the feed splash plate was replaced, the measured temperature jumped to 145°K. Assuming no change in VSWR, the additional noise power can come only from feed spillover past the 28-foot paraboloid and surface loss on it. The measured feed patterns have been used to calculate the spillover energy as 25°K. The remaining 22°K must come from resistive loss in the antenna surface, which would have to be 0.5 db to give this temperature.

In summary, there are indications that the (one-way) antenna gain is approximately 1.3 db lower now than it was two years ago. This loss in gain is due wholly or in part to an increase in the rms tolerance of the antenna surface.

The antenna has been in limited use during this reporting period because the tracking drive motors were being modified to facilitate observations of optically invisible radio sources. This modification is now essentially complete.

C. Observations and Data Analysis

During this reporting period, the moon was the only radio source observed. Both general lunation measurements and polarization measurements were made. The collection and analysis of the data are the responsibility of an M.I.T. student, who is writing a thesis on lunar radiation; however, advisory assistance in data analysis and interpretation is being provided by Lincoln Laboratory personnel.

Preparations for the 18 December 1964 lunar eclipse are under way. These include theoretical study of expected phenomena and data-reduction programming. A "dry run" of the experiment will be performed as soon as the antenna is operative.

Analysis of the data taken during the previous reporting period (when Venus was near conjunction) is proceeding slowly. Much editing of the data will be required before reduction is complete.

During this reporting period, a program to calibrate, average, and store data taken on radio sources was completed and tested on old data, as reported above. This program will allow data reduction to keep abreast of observations when we begin observing Taurus A during the next reporting period.

D. Construction

During the past reporting period, the 8.6-mm radiometer for Haystack was virtually completed. Testing of the radiometer awaits reception of a few waveguide pieces which are being fabricated outside the Laboratory.

The new antenna drive system requires new controls. A temporary open-loop motor control is almost complete. The full servo system should be completed within a month.

Bids were received on a new ferrite polarization switch, which will be used to permit instantaneous polarization measurements to be made on our present radiometers. A contractor was selected, and the switch was ordered.

MICROWAVE COMPONENTS
GROUP 46

I. INTRODUCTION

Group 46 contributes to the radar program through direct participation in specific projects, and through a program of general research which is closely related to the microwave requirements arising from radar projects. Contributions are made to the General Research Program through the support of Haystack Hill, operation of a high-power microwave laboratory, development of low-noise receiver techniques and receivers for space communications, and studies of very-high-gain antennas and antenna feeds.

II. HAYSTACK HILL MICROWAVE COMPONENTS

A. 7750-Mcps Transmitter

The design and construction of the VA-879, 100-kw transmitter are complete. The three transmitter racks and the water manifold are installed in the RF box, and the inter-rack and the RF box wiring have been completed.

Static testing (no RF) of the individual transmitter chassis, the inter-rack wiring, and the remote interlock and control panels is complete. The integration of all the control and system interlocks for the transmitter and the RF box is nearly complete. The flow rates for and pressure drops through the various water-cooled transmitter components are being checked out. Low-power RF tests will be conducted upon satisfactory conclusion of coolant tests. Final run-up of the transmitter will require magnet power, klystron filament current and klystron collector voltage from the Energy Systems, Inc., control and interlock system.

The development of the transistorized arc detector is complete, and a final version has been tested at 200 kw in a high-power waveguide ring. Detection of an arc in a reduced-height section of the ring was successful with the arc detector shutting down the ring driver tubes.

B. Waveguide Redesign

In order to eliminate a trapped TE_{11} mode resonance between the new antenna matching structure and the orthogonal mode transducer, the waveguide run from the orthogonal mode transducer to the antenna feed has been redesigned in 0.990-inch square waveguide instead of 1.122-inch square waveguide. All the necessary test components for this change have been designed and delivery is expected shortly.

C. Noise Rejection Filters

Manufacturing drawings have been prepared for the six-cavity-pair 8350-Mcps noise-reject filter for use in the high-power 7750-Mcps line. Construction of the filter is under way and should be completed during December. Following low-power tests and adjustments of the filter, matching irises will be added to the structure. The filter will then be tested at high-power levels.

D. Receiver Protector

A pulsed gas-tube attenuator has previously been developed in Group 46 as a receiver protector. The attenuator essentially consists of a 7-inch length of straight X-band waveguide with a neon-filled gas tube extending along its longitudinal axis. The gas tube projects through ports in E-plane bends at the ends of the straight section of guide. The tube is filled with neon at a pressure of 12 mmHg and is equipped with an oxide-coated cathode at one end and a simple anode at the other. In the fired state with a discharge current of 300 ma, the RF attenuation through the assembly is 120 db. In the unfired state the insertion loss of the attenuator is approximately 0.04 db. A gas-tube attenuator will be used in each of the receiver lines in the RF box when radar experiments are being performed.

A transistorized pulser will be employed to drive the attenuator tubes. A breadboard model of this unit has been built and found to work satisfactorily. It can be externally triggered and will operate with any duty cycle. A final version of the pulser is now under construction.

E. Low-Noise Receivers

All the low-noise receiver equipment has been delivered to the site. Mixer-preamplifiers, IF amplifiers, pump circuits, etc., have been installed in the box; power supplies as well as control and monitor equipment have been installed in the control room. The interconnecting wiring has been completed.

One parametric amplifier channel has been aligned and tested at room and liquid nitrogen temperatures. Considerable difficulty has been experienced with the second channel, primarily because of the problem of obtaining satisfactory replacement varactors. The two amplifiers in the second channel are currently being modified so that varactors from another manufacturer may be used. If the modification is successful, it will be possible to use varactors that are cheaper, more readily available and of higher quality than the diodes previously employed.

Production has started on the new electroformed parametric amplifiers. Some of these will be packaged for operation in dewars, and some will be installed in the closed-cycle refrigerator.

F. Radiometer Input Switch

A Ferrotec, Inc., Faraday rotator will be employed to alternately switch the radiometer receiver input between the antenna terminals and the output of a reference noise source. With the coil current optimized to give at least 30 db of isolation at 7750 Mcps, the minimum isolation over the 7500- to 8500-Mcps band is approximately 20 db. At 7750 Mcps, the insertion loss is about 0.2 db.

G. Waveguide Gaskets

Two types of X-band waveguide gaskets have been developed which are more suitable for high-power operation than presently available commercial gaskets. These gaskets are fabricated from annealed copper. One type is known as the narrow-land gasket (NLG), and the other type is termed the wide-land gasket (WLG). These gaskets are designed for use with stainless steel flanges. The NLG can be reused once without resizing, but the WLG can be

reused at least five times and even improve slightly with usage. However, the NLG withstands higher power levels than the WLG.

In one series of tests with WR 112 waveguide and stainless steel flanges, the WLG broke down at an average power level of 244-kw CW, but the NLG arced over at an average power level of 324-kw CW. In these tests, the gaskets were not resized, and no special attention was given to the gasket alignment. Under similar conditions, a commercially available Parker-type gasket withstood only 174-kw CW.

In a second series of tests, the gaskets were resized and care was given to the gasket alignment. Under these conditions, the WLG withstood an average power level of 511-kw CW, and the NLG withstood power levels from 525- to 550-kw CW. (It may be of some interest to note that these tests were conducted at power levels in WR 112 waveguide that have not been duplicated in any other laboratory.) For purposes of comparison, resized and carefully aligned Parker seals could withstand power levels of only 196-kw CW.

III. STUDY OF SURFACE RESISTIVITY OF MICROWAVE COMPONENTS

The purpose of this study is to investigate methods of minimizing power losses and noise temperatures by appropriate treatment of the surfaces of microwave components.

During this reporting period, effort has been directed in the following areas:

> Protective Coatings:— The last few samples with a new electroless gold coating have been measured for RF surface resistivity and are presently undergoing an artificial aging experiment.
>
> Electroforming:— During some earlier tests it was noted that copper components electroformed on stainless steel mandrels had a much higher RF surface resistivity than those components electroformed on aluminum mandrels. Experiments are under way, in conjunction with Group 73, to determine the reason for this and to attempt to improve the surface resistivity of components made in the near future on stainless steel mandrels.
>
> Electroplating on Beryllium Copper Coatings:— Tests are also under way which will hopefully demonstrate that the surface resistivity of beryllium copper castings can be improved to a level which is comparable to that of fabricated copper components. Past experiments have pointed out many pitfalls which hinder the accomplishment of a successful electroplated coating.

A report, which covers the entire series of experiments, is now in preparation.

IV. SOLID-STATE AMPLIFIERS

A. Cooled, Varactor-Diode Amplifiers

Hardware is under procurement for the assembly of thirty L-band varactor-diode parametric amplifiers. The amplifiers will be cooled by small, separate Joule-Thomson expansion heat exchangers. Twelve amplifiers will be employed in one receiver system. Each amplifier and cooler will comprise a self-contained unit, which can be removed and replaced without shutting down the whole system. A common compressor will supply high-pressure nitrogen gas as a refrigerant to all twelve heat exchangers.

B. Wide-Band, X-Band Parametric Amplifiers

Design techniques have been devised for a waffled coaxial resonator, which will be employed as a broadbanding resonator in a wide-band, X-band parametric amplifier. The resonator behaves as a parallel-resonant circuit at some desired center frequency and as a wide-band reject filter capable of discriminating against signals in any mode at higher frequencies.

One model was designed to resonate at 8050 Mcps with a 3-db bandwidth of 1200 Mcps and a rejection band from about 12.5 to 30 Gcps. The model actually resonated at 8050 Mcps with a 3-db bandwidth of 1100 Mcps. The rejection was greater than 20 db from about 15 to 18 Gcps. Limitations in the instrumentation have restricted the maximum frequency of measurement to 18 Gcps.

C. Diode Measurements

Measurements of varactor-diode parameters at S-band with the triaxial diode holder have continued. The diode holder and the associated instrumentation have been modified to permit the detection of signals as low as −90 dbm. This capability is important inasmuch as we are concerned with small signal measurements of a nonlinear device.

Data have been taken on various diode packages to permit us to make convenient evaluations of varactor cutoff frequencies.

A report has been received from a vendor of InSb varactors regarding several diodes which opened or shorted in use. The vendor indicated that the diode failures resulted primarily from the transmission of mechanical stresses to the junction by the contacting screen and recommended the use of a standard diode package which is larger than the micro-pill package. Six diodes were obtained in the larger package and have been recycled in liquid nitrogen for a period of three months. Of the six diodes supplied, four have maintained their original characteristics, and two have suffered an appreciable degradation in characteristics.

A report that will establish precise meanings for diode package inductance and capacitance is in preparation. This report will show how these elements can be combined with the circuit elements of the diode junction and the equivalent circuit of a waveguide or coaxial diode mount to form a total equivalent circuit that has greater validity than those presently used.

D. Cryogenic Temperature Control

The temperature field within a dual-dewar system is such that the temperature of a diode holder may be controlled by varying the distance between the holder and the fluid surface in the inner dewar. Using this approach, an automatic temperature control system has been constructed and will be evaluated during the next reporting period.

V. MICROWAVE PULSE-COMPRESSION RADAR

Experiments are under way to determine the feasibility of building a high-power microwave pulse-compression radar at L-band. In a scheme under investigation, a long resonator is charged from a moderate power microwave source and, after a suitable interval, a switch is closed to discharge the resonator into an antenna.

The switch consists of an air gap, which is triggered by an ultraviolet source. It has been found that the switch definitely operates at a high overvoltage (about three times the CW breakdown voltage). The switch also depends on the complete absence of electrons in the high-field region for its ability to hold off high power. If electrons are present, the switch will break down prior to the application of the ultraviolet trigger. It is believed that electrons are produced during a charging pulse by the ion bombardment of the electrodes. These ions are normally present from a previous discharge. An air stream has been found to be very effective in removing the ions and thus improving the holdoff properties of the switch.

With the particular pulsed ultraviolet source employed, the statistical time lag is less than half a nanosecond. The formative time lag has been measured, and the value determined agrees well with the lag measured for DC overvoltages by various experimenters. The best pulse rise time yet measured was about 5 nsec. The arc loss was measured with three different experimental arrangements. It was concluded that the arc sustaining voltage is nearly independent of current and equal to 0.5 to 1.0 times the CW breakdown voltage of the gap. Because of the high ratio of sustaining to holdoff voltage, the arc loss is rather high (1.5 to 3 db). The best pulse yet achieved had a peak power of 2.5 Mw, a pulse length of 30 nsec and a 5-nsec rise time with an arc loss of 2.2 db. It was produced with a straight resonator at atmospheric pressure. It is expected that a much higher power pulse will be produced in a pressurized ring resonator with an improved air flow system for ion removal.

In the course of checking the various microwave circuits for transient response, it was observed that 18 feet of WR 650 waveguide degraded the rise time of a step function at 1300 Mcps to about 8 nsec. This value was confirmed theoretically. This result dictates the use of a TEM transmission line or a very-short-waveguide run between a high-power, short-pulse generator and the antenna.

VI. L-BAND WAVEGUIDE COMPONENTS

The H-plane bends and E- and H-plane panty sections of the compensated double-mitre bend type have been designed in WR 650 waveguide. Each component has a VSWR of less than 1.01 over the frequency range from 1250 to 1350 Mcps. The work is being expanded into a general design study of double-mitre bends.